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Artificial Neural Network (Narx Algorithm): prediction of dissolved oxygen in the Sinu River (Colombia)

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Abstract

This paper considers the prediction parameter turbidity in the raw water quality specifically the dissolved oxygen in the Sinu River (Colombia), from sampling at this body of water, in order to estimate relevant conditions of raw water quality and aspects in the use of water resources in the river basin.

Keywords: Raw water, artificial neural network, prediction, dissolved oxygen.

INTRODUCTION

The technique used was the Artificial Neural Network (ANN). This technique has different algorithms training as BackPropagation, Newton, Levenberg Marquardt (LM), among others. The most common and used is BackPropagation; but in the case of the present investigation the best results was obtained with the Levenberg Marquardt (LM). The artificial LM neural network is a feed-forward neural network. This network is composed of individual processing elements called neurons that resemble as brain neurons [1]. The model of each neuron can be represented as A = F (WP + b) where W = [$w_{1,1}$, $w_{1,2}$, ..., $w_{1,R}$] and P = [p_1, p_2, ... ,$_R$ p], the P vector are inputs, W is the vector of weights for each input, the parameters $w_{1,R}$ and b are adaptive [2]. Each neuron adds the weighted inputs and then apply a linear or nonlinear function to the resulting sum to determine the outputs. Between the most used functions are the step function, sigmoid and ramp [3]. Neurons are arranged in layers and combine through excessive connectivity. This permits specifying multiple criteria input and generating multiple output recommendations [1]. The Levenberg-Marquardt (LM) algorithm is a nonlinear optimization based on the use of second order derivatives [3]. LM algorithm find the minimum of the function F(x), that is a sum of squares of non - linear functions.

$$F(x) = \frac{1}{2}\sum_{i=1}^{m}[f_i(x)]^2 \quad (1)$$

Take the Jacobian $f_i(x)$ that is termed as $J_i(x)$, then the Levenberg-Marquardt method seeks the solution of P given by equation

$$(J_k^T J_k + \lambda_k I)P_k = -J_k f_k \quad (2)$$

where λ_k are not negative scalars and I is the identity matrix [4].

The artificial intelligence technique “Artificial Neural Networks (ANN)”, has been working in centralized air conditioning of ice water, predicting consumption of water and river flows, in assessing the quality of drinking water, in the control of process water treatment, plant management wastewater treatment, purification of underground waters and the identification of water pollution sources, in terms of dioxins and sediments in rivers [5]. Other results of studies by Hamoda (1999) and Grieu (2005), have established that the performance of the WWTP can be predicted through a neural network and also other studies such as Hamed (2004) and Mjalli (2007), Tomenko (2007), have shown that neural networks has surpassed regression models used in wastewater treatment plants [6]. Also, studies have been conducted by Lin (2008), Dogan (2009) and Singh (2009) using neural networks for the prediction of river water quality in river basins. However, it has also been found in studies conducted by Beck (2005) an accumulated error effect over a period of several years, which although it generates a considerable approximation in the cumulative predictions in multiple periods of time, is highly significant and influential in the quality water in the basin [6]. Another application has been in the analysis and diagnosis of a wastewater treatment plant (activated sludge technology), due to the high variability of the concentration of the parameters of the raw waste water (tributary) and the knowledge of the performance of the processes and unit biological operations present in wastewater treatment plants, therefore, an analysis was made through neural networks, to discover dependencies between the process variables and the behavior of the wastewater treatment plants and their potential for application to other treatment plants wastewater [7]. Linear statistical and neural network models for the application of water management in watersheds have been applied, taking into account the effluents of wastewater treatment plants and non-point sources (rainfall run-off). Therefore, in this study the environmental quality in the basin of Sinu River (Colombia) using the technique of artificial neural network with Levenberg Marquardt algorithm we will be assessed.

MATERIALS AND METHODS

The method used is a combination of real, exact observation and knowledge of an empirical, complex situation and inductive reasoning, which would consist of deriving a new knowledge from particular phenomena and knowledge already obtained, and establishing propositions analyzed from their causes and real effects, i.e., from the particular to generally [8, 9]. It is mentioned, that according to the analysis and scope of the results, the type of research is analytical – quasi- experimental, since analyzes an event and comprising in term s of their obvious aspects, and also discover elements that make up the whole and connections that explain their integration, i.e., promotes the study and deeper understanding of the event under study [10, 11, 12].

Precipitation information obtained from sampling in the period 2008 to 2014 by the Autonomous Regional Corporation of the Sinu and San Jorge Valley (CVS).

RESULTS

The implementation of the artificial neural network using the Levenberg Marquardt, was obtained by importing the data over time and then environmental quality was estimated according Dissolved Oxygen data input, for it was established the following design:

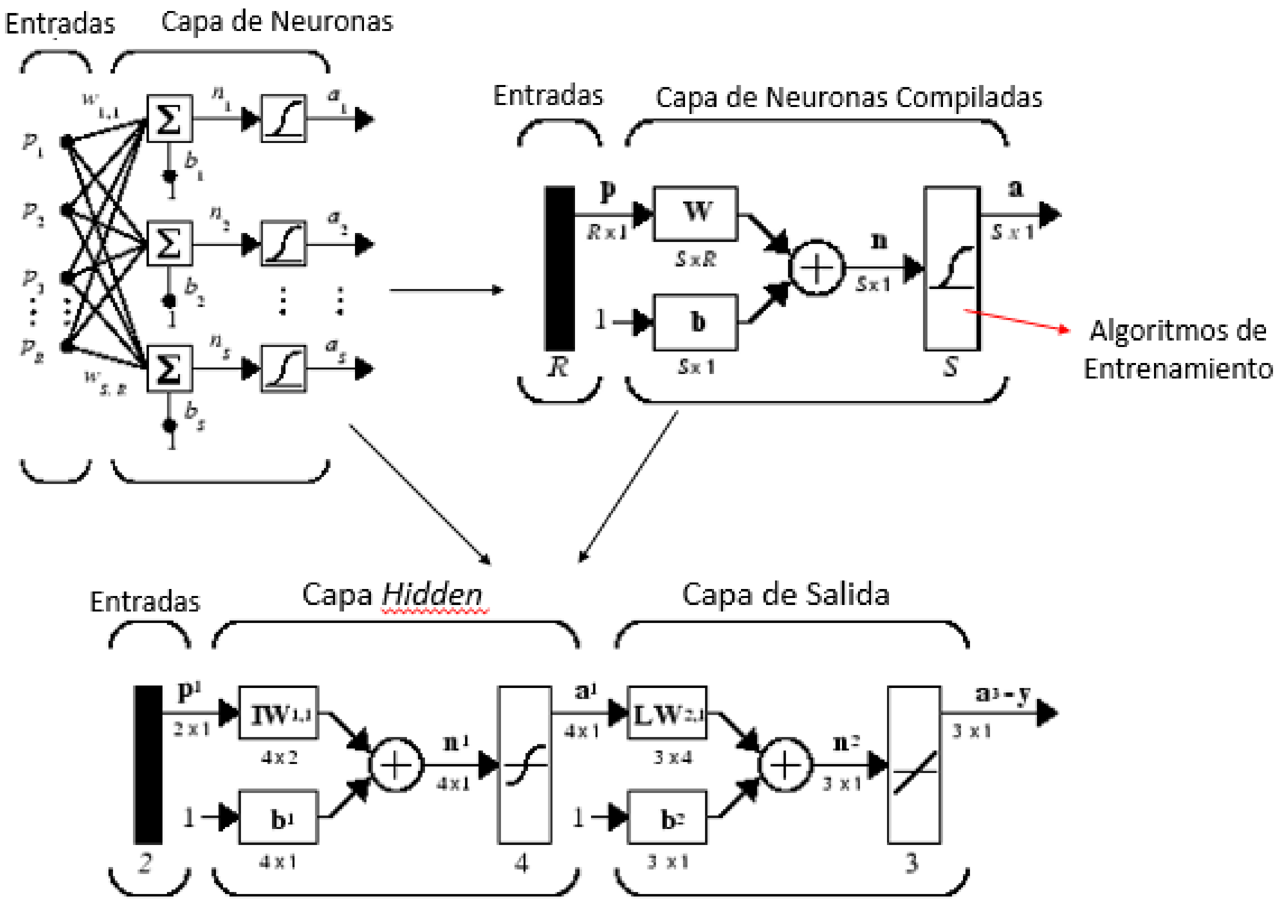

Figure 1: Proposed *Feedforward* Neural Network Model.

In figure 1, a block of entries was observe in the first layer, with acceptable results of four layers and can be used in the second stage of network design, which corresponds to a standard design of the artificial neural network known as *feedforward*, usually having one or more *hidden* layers with the respective training method, followed by a linear output layer. In terms of the training layer *(hidden)* it is characterized by a training criterion or activation which can explicitly use the Levenberg Marquardt algorithm, which has a function expressed as follows: $F(x) = \frac{1}{2}\sum_{i=1}^{m}[f_i(x)]^2$, be the Jacobian of $f_i(x)$ defined as $J_i(x)$, in such way that the algorithm searches iteratively, in the given direction, for the solutions to the required equations: $(J_k{}^T J_k + \lambda_k I)p_k = -J_k{}^T f_k$, where λ_k are the non-negative scalars and I corresponds to the identity matrix. Based on the above, the neuronal network is formed in Matlab and 50 neurons were defined, the decision of the number can become subjective, given the fact that, depending on the application, the decisive factor lies in the result obtained.

Sinu River

The Sinu river basin is located in the northwest of Colombia, in South America, more specifically in the southwest area of the Colombian Caribbean coast, within the Departments of Cordoba and Antioquia. It originates in the Paramillo massif, which ranges between 7º 8’ 9” and 9º 27’ 2” north latitudes and 75 ° 55' 31" and 75 ° 58 '18 " west lengths. The Sinu River is the main water system in the department of Cordoba, since besides fertilizing its valley - which is the stage of an intense agricultural and livestock activity - it represents an important supplier of fish species, thus becoming one of the main ecosystems of the Colombian Caribbean coast [14].

The river is stored by the Urra 1 hydroelectric dam, within coordinates 8º 01′ 10” north latitude and 76º 12′ 08” west longitude. Along its course, Sinu River has a complex interaction with streams, marshes and swamps that flow into it and regulate its pikes during maximum flood level periods [14, 15].

Dissolved Oxygen concentration (DO), biochemical oxygen demand (BOD) and Total Kjeldahl Nitrogen (TKN) is not uniform in the Sinu River, either in the stream or throughout the year. The DO varies between 3.7 mg / L and 5.5 mg / L; BOD between 1.0 mg / L and 2.0 mg / L and TKN is less than 1.0 mg / L, near the dam. Nonetheless, in remaining stream of the Sinu River, the DO varies between 6.0 mg / L and 7.0 mg / L; BOD, between 1.0 mg / L and 2.0 mg / L and NTK is less than 1.0 mg / L [16].

The Sinu River is the main source providing water to the aqueduct systems in the department of Cordoba (Colombia) [17]; however, its turbidity levels are higher than 1.200 NTU, during the rainy season, and even higher than 40 NTU, during the dry season [18].

In Figure 2, data traffic analyzed, generates high variability and heterogeneity in dissolved oxygen concentrations in the body of surface water, indicating a good health condition of the river, which considered a representation of the degree of quality body of water along basin and at the same time some scatter points together cloud data analyzed in the analyzed period 2008-2014

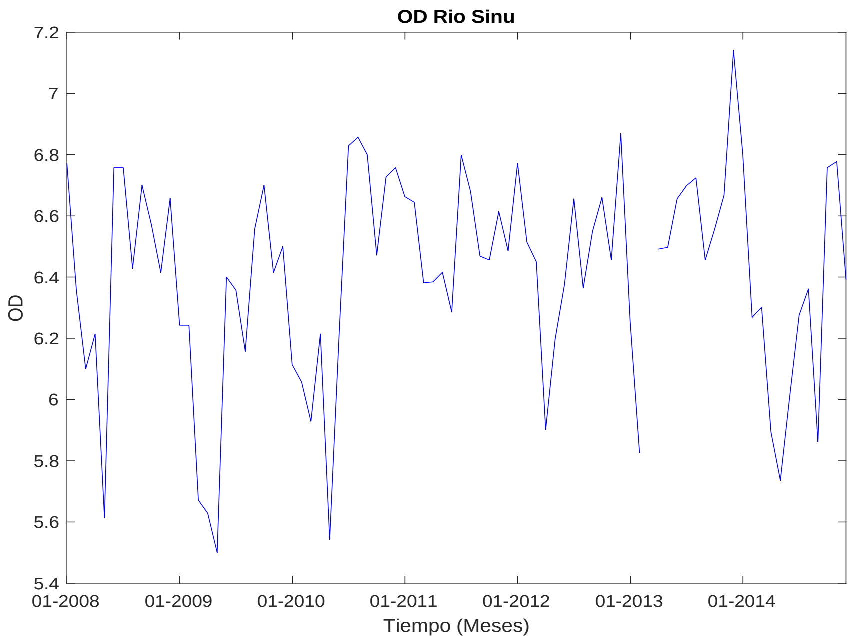

Figure 2: Dissolved Oxygen Data in the sample

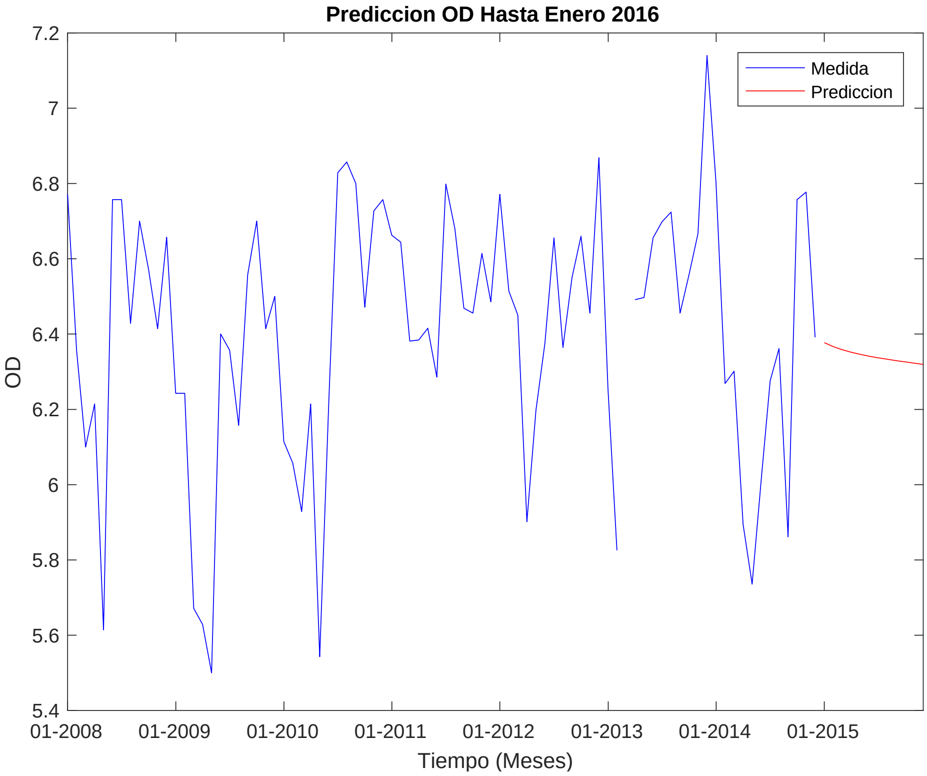

Figure 3: Prediction of dissolved oxygen.

In Figure 3, is observed how the line features is the indicator of environmental quality of the water body measured as dissolved oxygen, a volatile fluctuation occurs with a low frequency turn like in the analyzed period (2008-2014), with a high dispersion results environmental quality for surface water; a decreasing prediction is observed in the following period of the year 2015 to 2016, but within the condition of good health of the river.

This may relate to the conditions of water quantity in the Sinu River, where it is mentioned that the flow averages river during the months of March and April are kept in a range of 200 m^3/s to 400 m^3/s, with peaks ranging from 70 m^3/s up to 600 m^3/s, while in the months from May to August, the average flow rate ranges from 400 m^3/s to 600 m^3/s, with peaks from 250 m^3/s to 850 m^3/s. Finally, during the months of September to December, the average flow range is 200 m^3/s to 600 m^3/s, with peaks of 70 m^3/s to 700 m^3/s, which generates a dilution condition of the pollutants discharged and the adequate self-recovery of the body of water.

CONCLUSIONS

By using artificial neural network with the Levenberg Marquardt algorithm to estimate the environmental quality in terms of dissolved oxygen in the body of surface water in the case of the Sinu River, it is observed that by using a layered compiled neurons and a layer of training, the result is very favorable in emulation of the environmental quality of the experts based on the results of performance, which serves to make environmental decisions in any space of time and even during interannual analysis periods and used to predict the behavior of the parameter (oxygen dissolved) in later periods and establish the quality or health of the body water, to consider actions for improvement or maintenance of water quality in the watershed.

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